Arctic Ocean topostrophy from current meters

Greg Holloway
Institute of Ocean Sciences, Sidney B.C., Canada

Arctic Ocean Models Intercomparison Project (AOMIP)

AWI	Alfred Wegener Institute	Germany
GSFC	Goddard Space Flight Center	USA
ICMMG	Institute of Computational Math and Math Geophysics	Russia
IOS	Institute of Ocean Sciences	Canada
LANL	Los Alamos National Laboratory	USA
NERSC	Nansen Environmental and Remote Sensing Center	Norway
NPS	Naval Postgraduate School	USA
NYU	New York University	USA
POL	Proudman Oceanographic Laboratory	UK
RAS	Russian Academy of Science	Russia
RCO	Rossby Center, Meteorol. & Hydrol. Institute	Sweden
UAF	University of Alaska at Fairbanks	USA
UCL	Universite Catholique de Louvain	Belgium
UL	Universite Laval	Canada
UW	University of Washington	USA
WHOI	Woods Hole Oceanographic Institution	USA

Why? 1. to aid understanding the Arctic
2. global climate models are often wrong in Arctic

What are the differences among models outputs? Why?
What are differences between models and observations? Why?
Can we improve Arctic ocean/ice models?

To compare models, T and S are simple. Average, make heat or "freshwater" storage, etc. What to do about **V**?

Define "topostrophy" $\tau \equiv \mathbf{f} \times \mathbf{V} \cdot \nabla H$, a scalar averages like T or S.

$\tau > 0$ means keep shoaler to right (in NH). E.g., Arctic observers refer to prevalent "cyclonic rim currents"

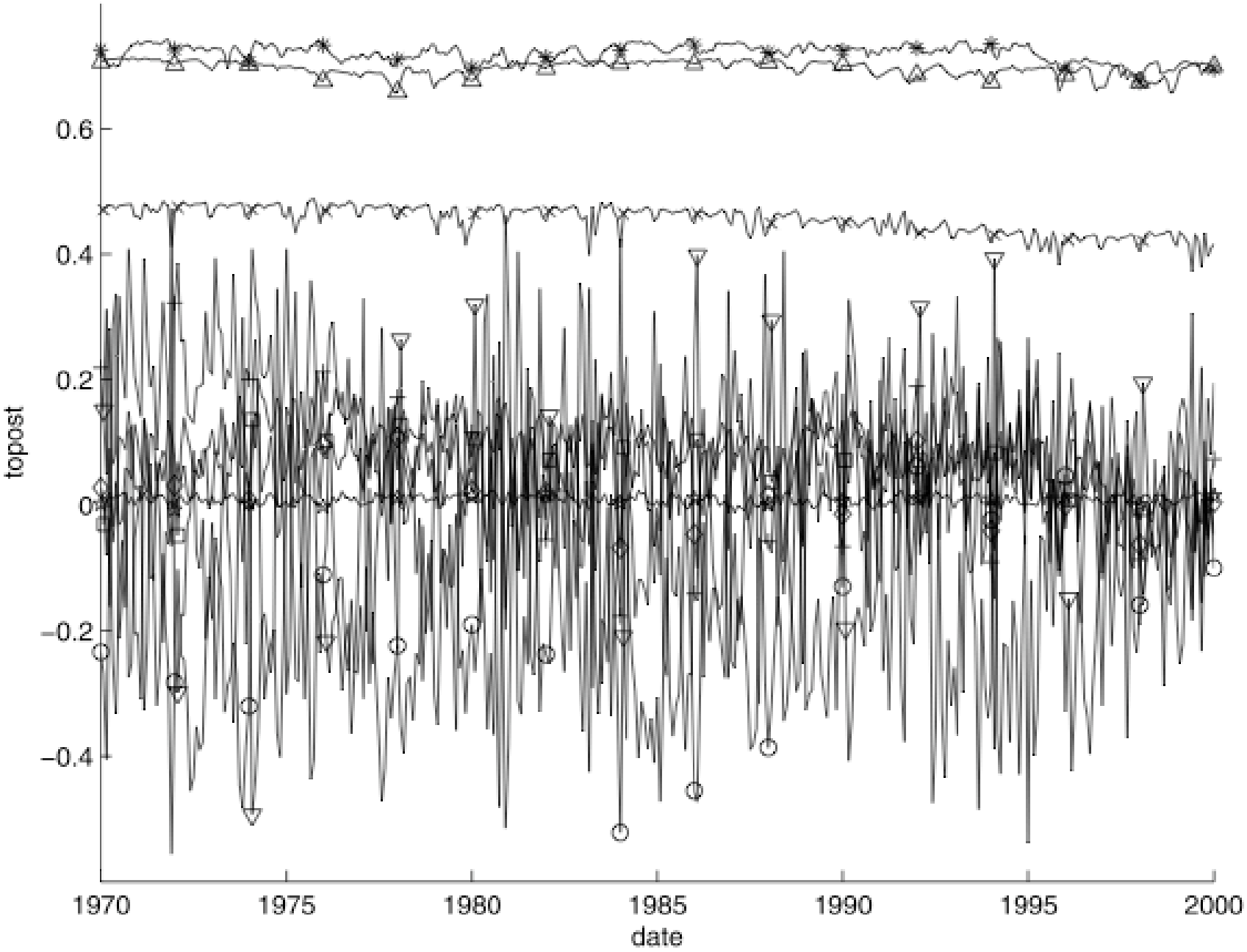
Normalize averages of τ by r.m.s. $\mathbf{f} \times \mathbf{V}$ and ∇H :

$$\tau \equiv \frac{\left\langle \mathbf{f} \times \mathbf{V} \cdot \nabla H \right\rangle}{\sqrt{\left\langle \left| \mathbf{f} \times \mathbf{V} \right|^2 \right\rangle \left\langle \left| \nabla H \right|^2 \right\rangle}}$$

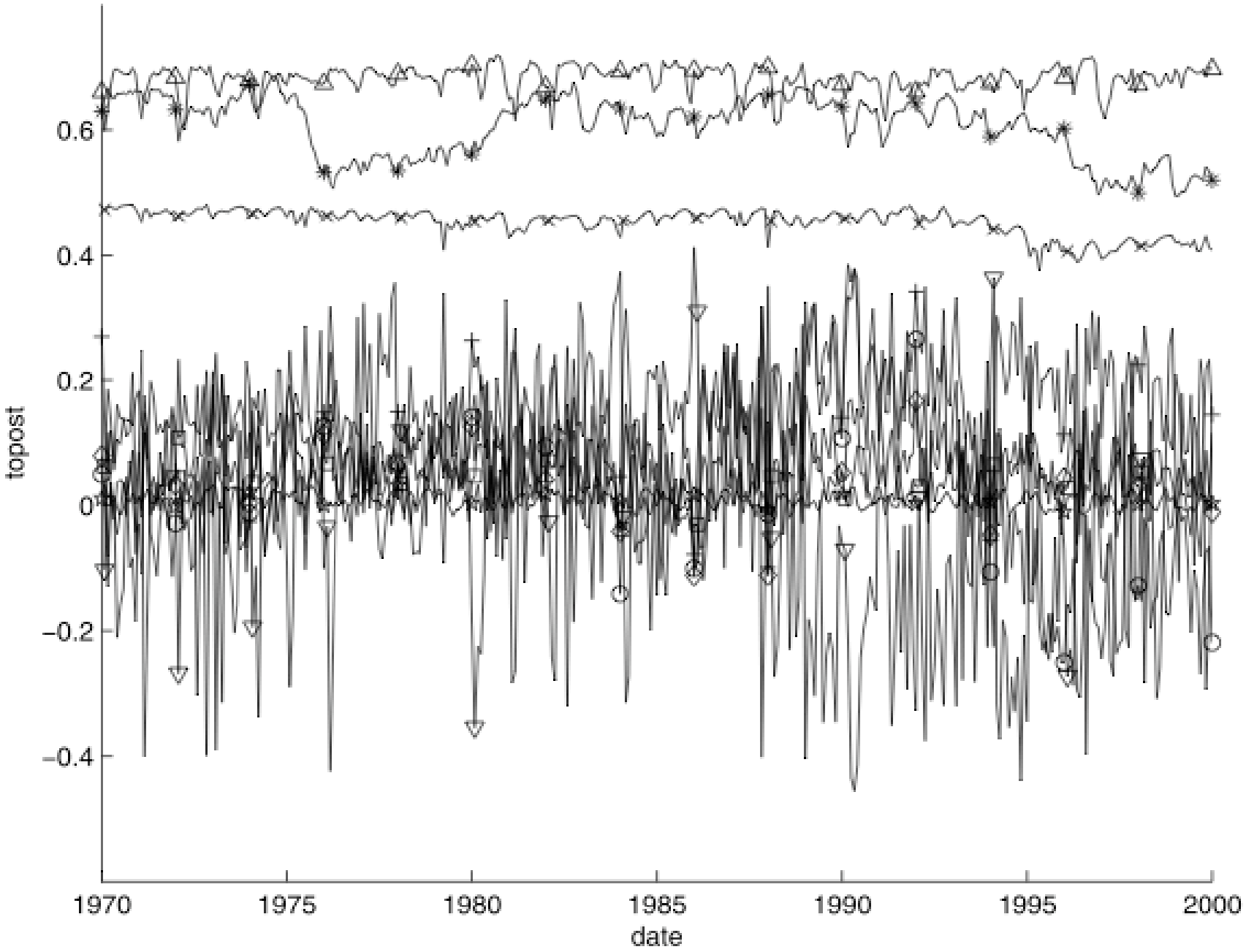
Then $-1 \le \tau \le +1$

Compare Arctic models by averaging τ over various regions:

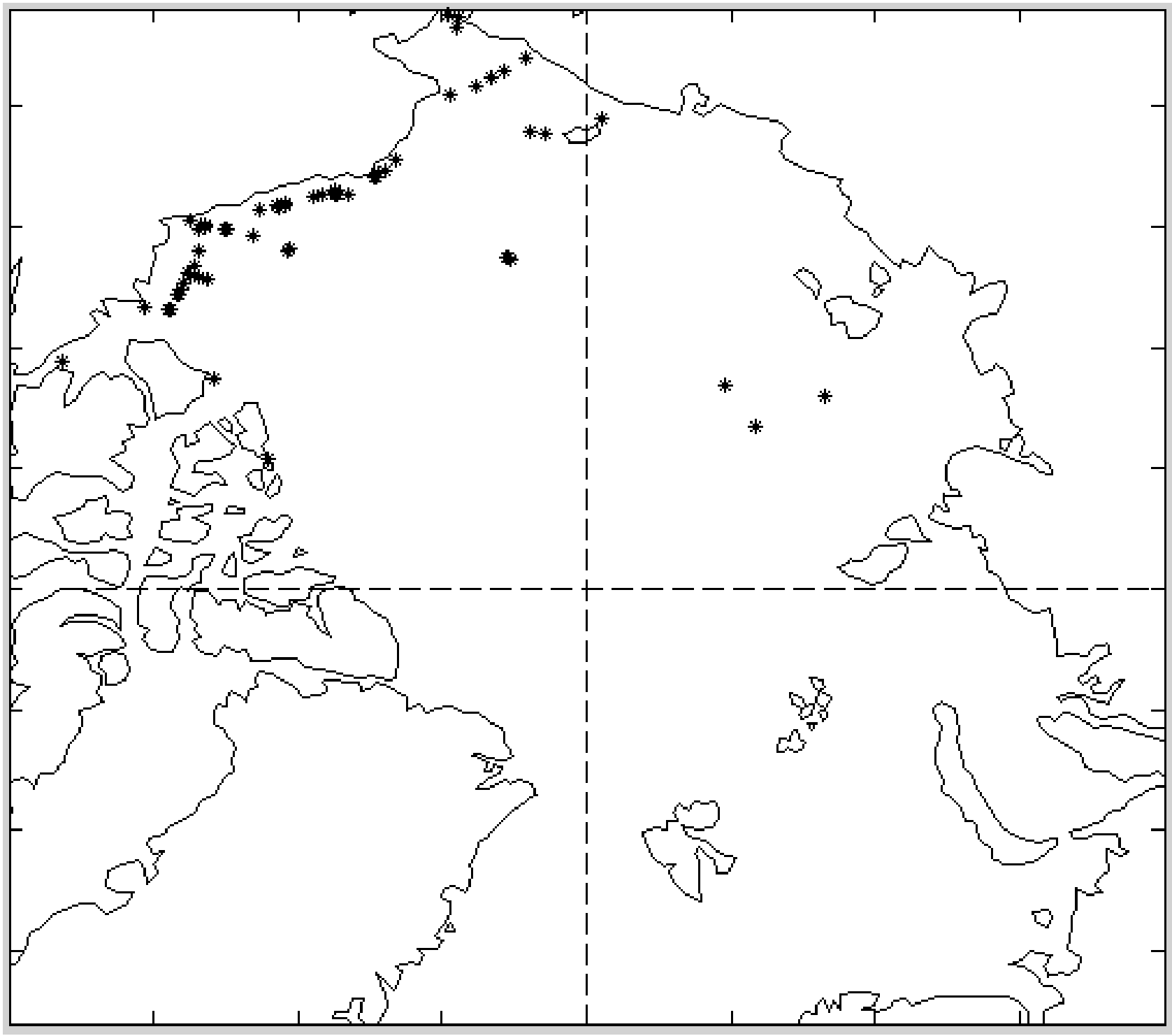
Topostrophy averaged over Amerasian basin



Topostrophy averaged over Eurasian basin

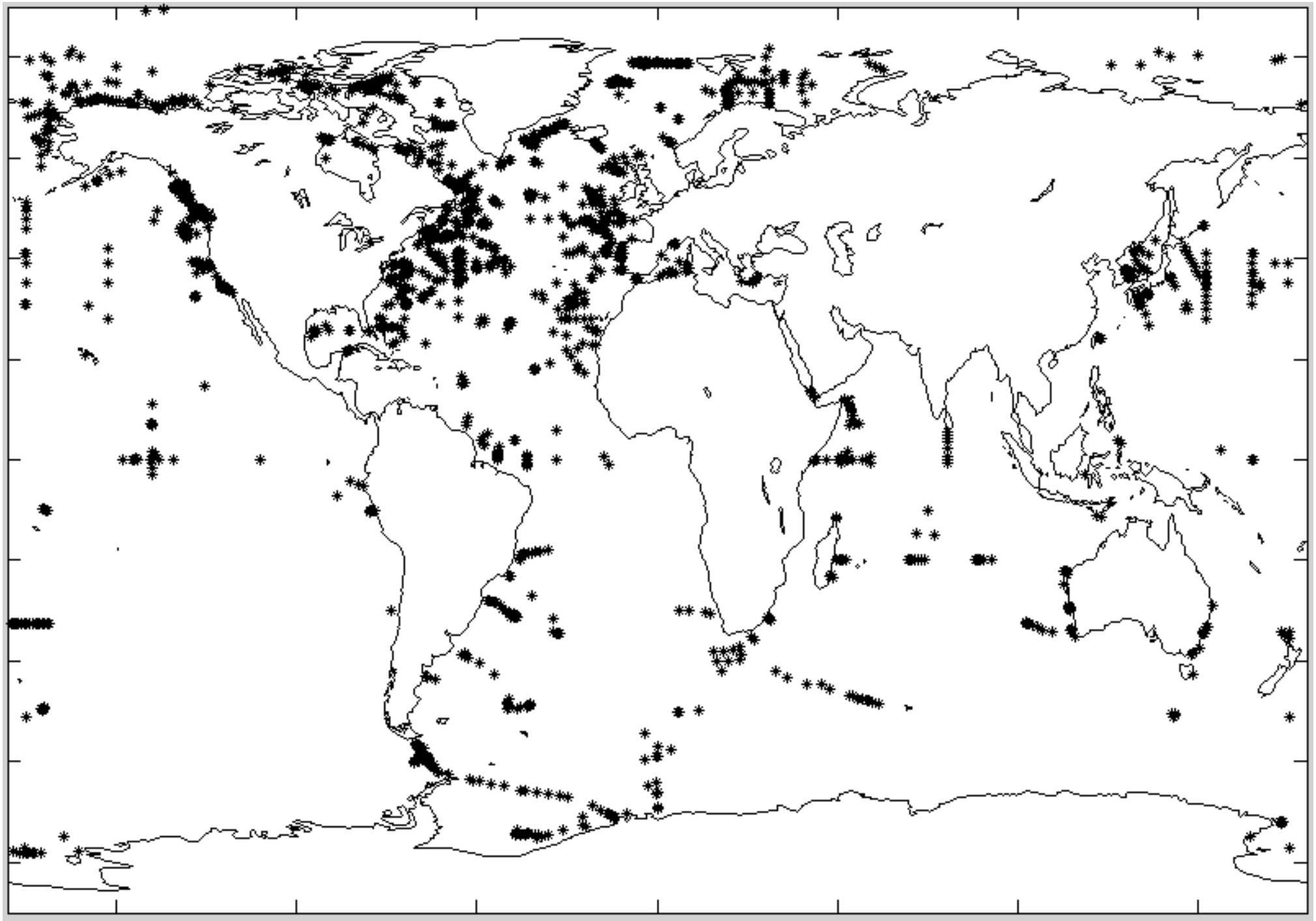


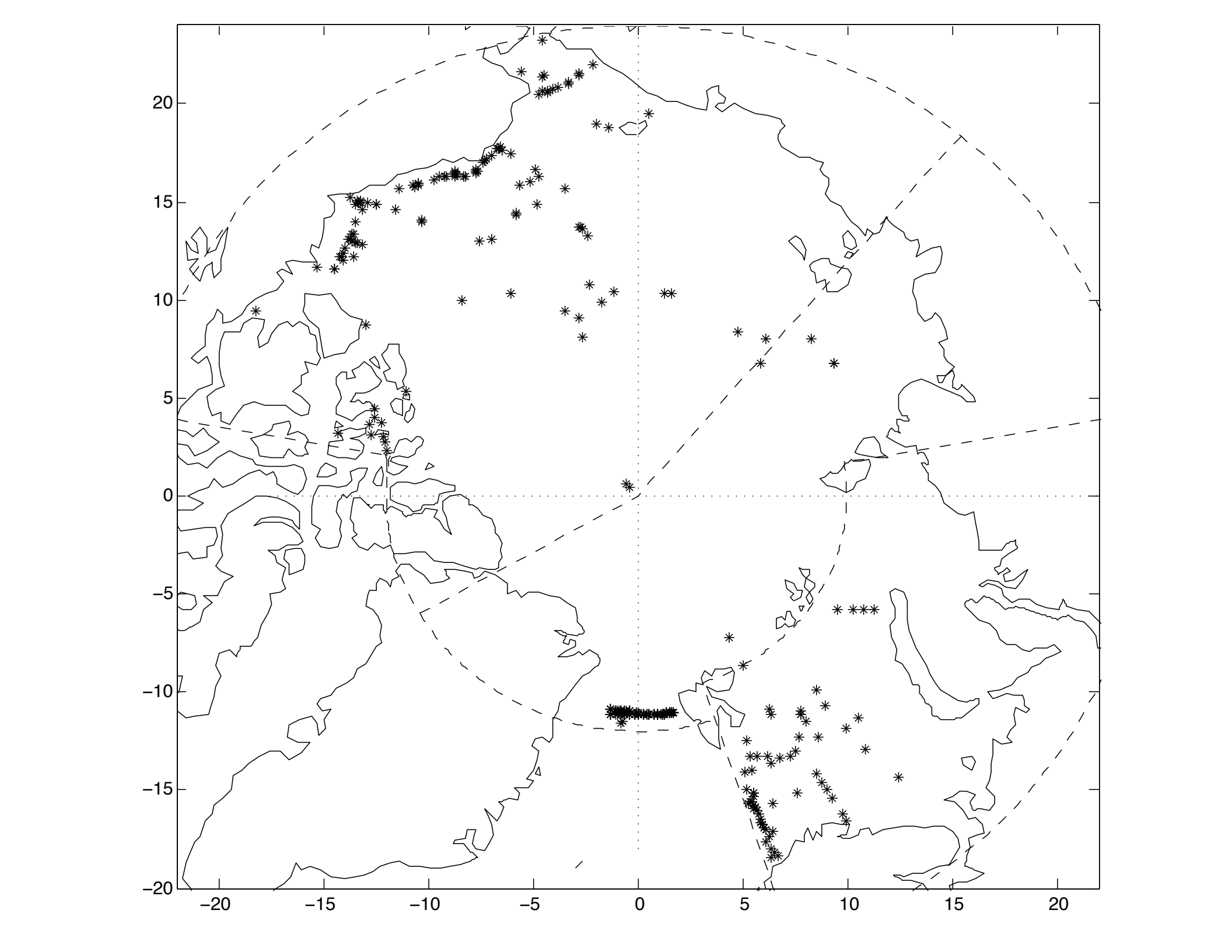
Modest beginnings (2006) thanks to Rebecca Woodgate, Humfrey Melling, Paula Fratantoni



Progress! 17147 records over 83667 months!

with particular thanks to Joseph Bottero (formerly OSU) and Doug Gregory (BIO)




20
15
10
5
0
−5
−10
−15
−20
−20
−15
−10
−5
0
5
10
15
20

Back to global dataset. 17000 is a lot, but ...

... so what?

We get to see oceans in a new way (τ)
using a large (growing!) resource.

Simplest: average all places, all depths, all times ==>> + .22

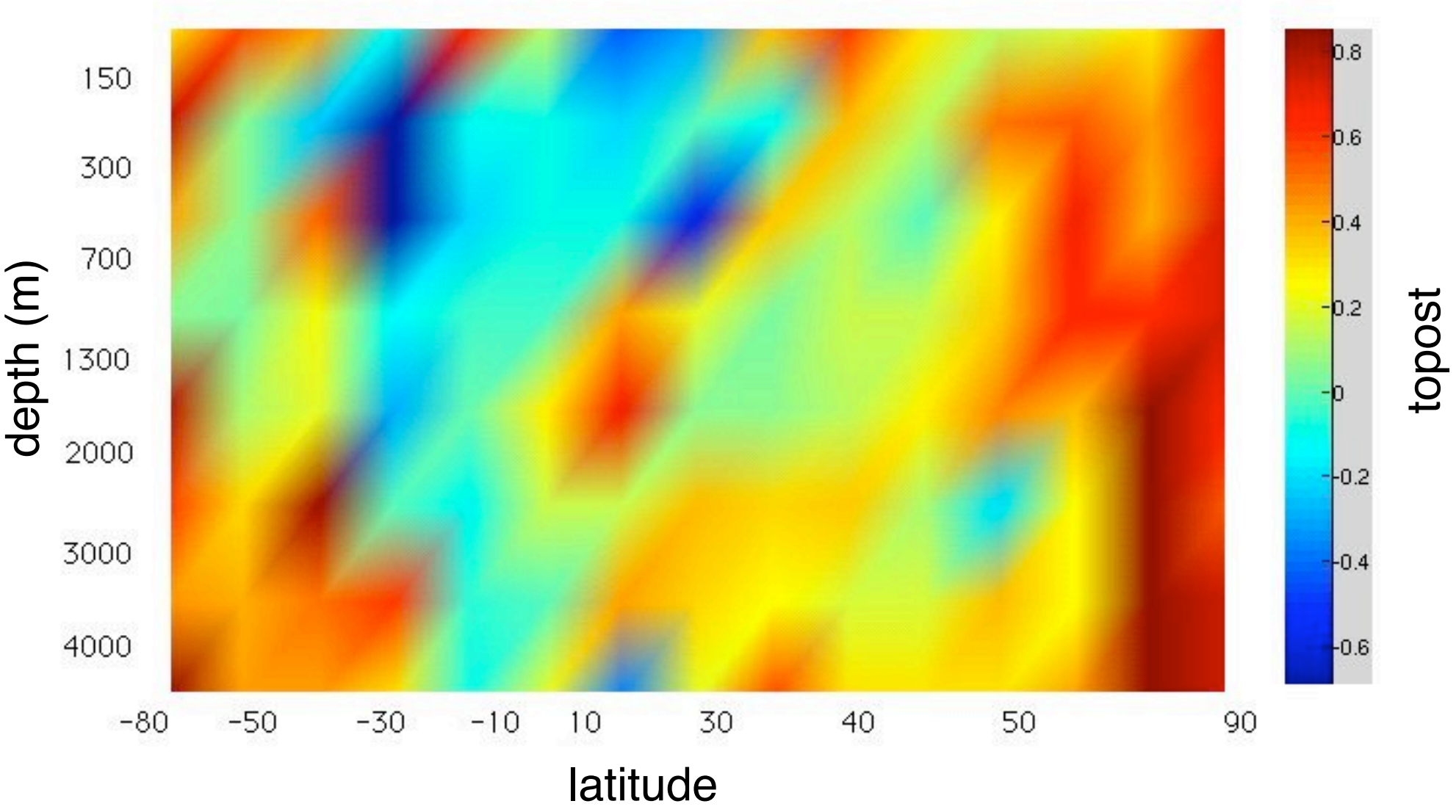
Confidently (? work in progress) +.2 to .26

Error compensation (in progress) will make this more positive.

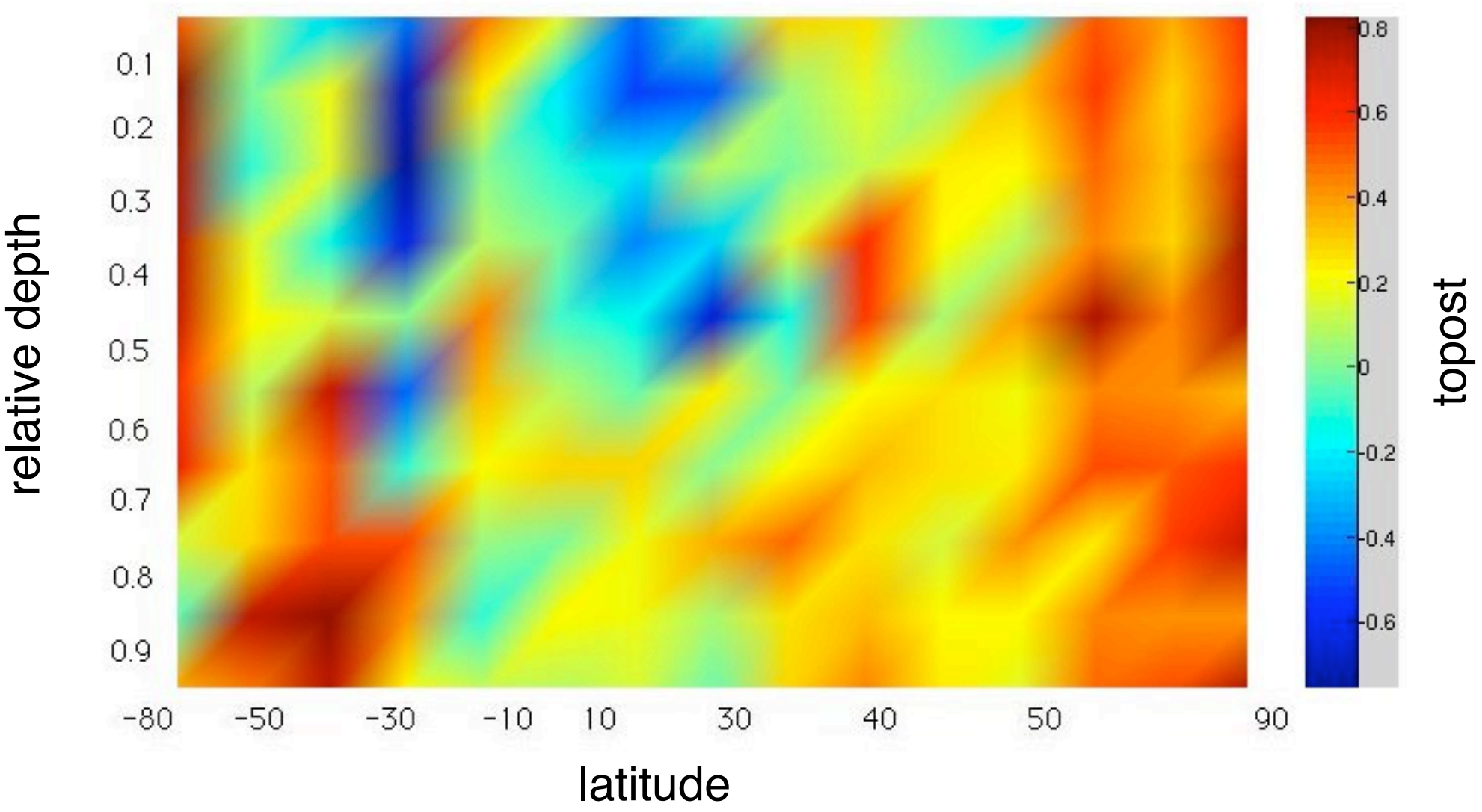
why .22 ? and why "+" ??

How does τ vary with depth, latitude, region ...?

Separate by depth and latitude. Samples per bin become awkward.



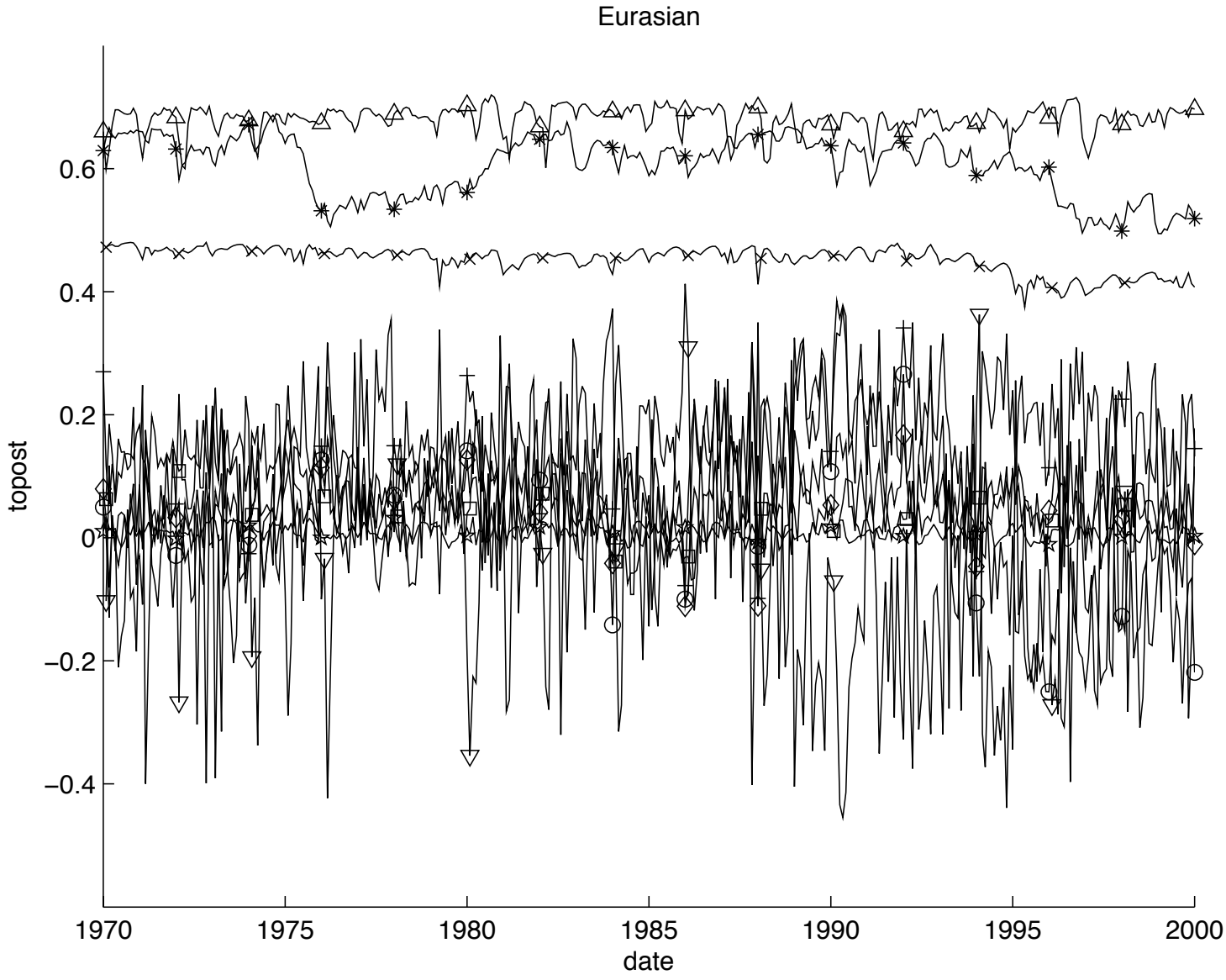
Absolute depth may confuse things. Bin by fraction of total depth?


relative depth
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
-80
-50
-30
-10
10
30
40
50
90
latitude
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
topost

Can we put this to use (a) measuring models, (b) improving theories?

Recall AOMIP (JGR 2007): Most models show small, highly variable

Three do “something else”.



Caution: these are basin average (not current meter) topostrophy.

We need to sample models at the CM locations. All the CMs are at different times for different durations. Make climatology from all CMs (min. duration 1 month). Ask for long term averages from modellers (varies from 5 yr to 50 yr for different models). So, who wants to play?

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1. Canada Centre for Climate Model "CGCM"
2. Community Climate System Model
3. Dept Fish and Ocean, Bedford Inst., "OPA"
4. Goddard Space Flight Center "POM"
5. 1. z-level 2. sigma-level
6. Inst. Mecanique Grenoble, 0.25° global
7. Japan Earth Simulator, 0.1° (to 75° latitude)
8. Los Alamos National Lab, 0.4° global "POP"
9. 1. biharm. friction 2. biharm. neptune
10. Proudman Oceanogr. Lab, "MOM3" global
11. 1. friction 2. neptune
12. Universite Laval, "AIM"
13. 1. friction 2. neptune
14. Wood Hole Oceanog Inst, barotropic Arctic

and more soon:
Norway
Russia
Germany
more US ...

For each model:

1. AOMIP
2. whole domain

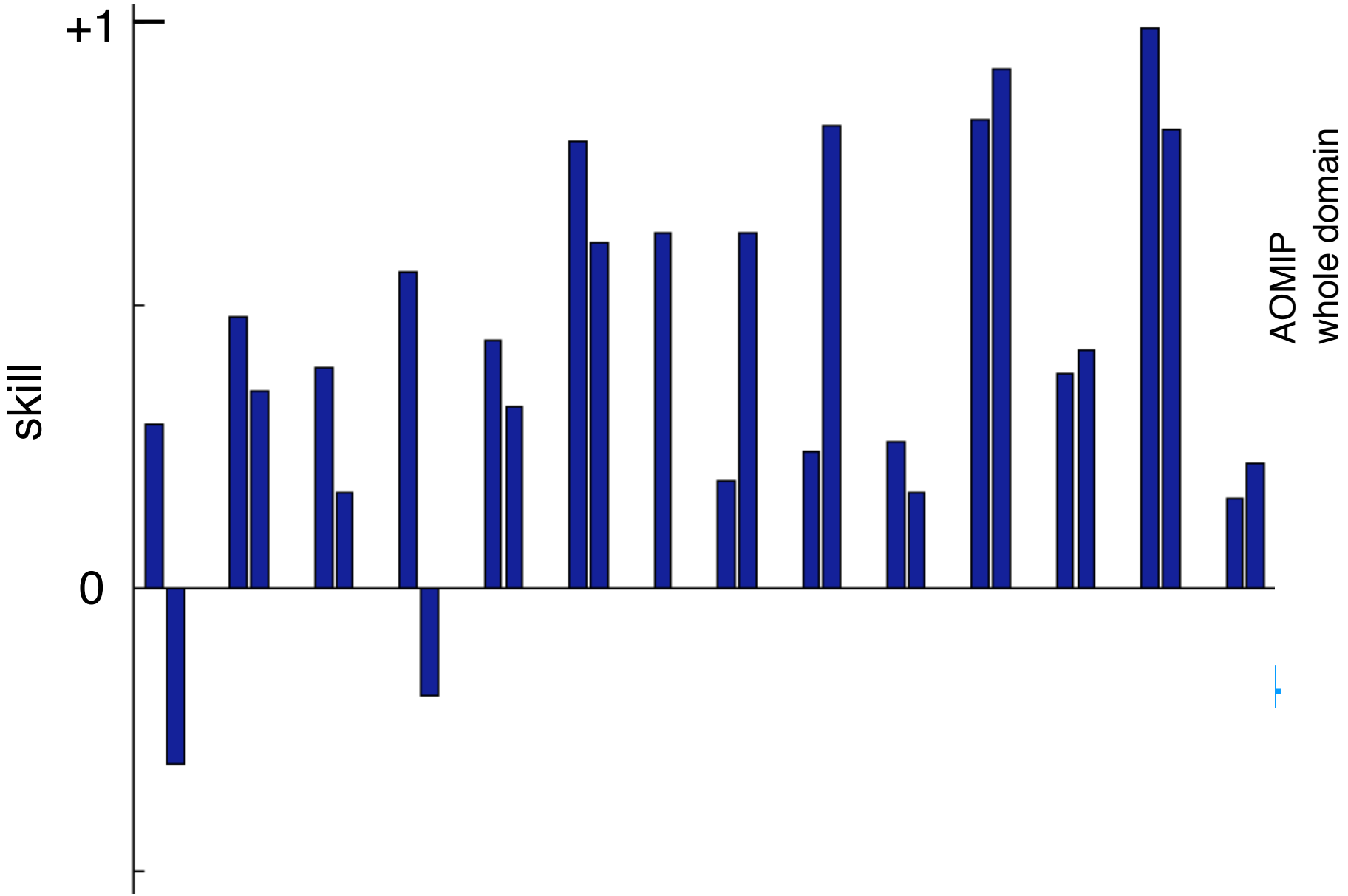
14 models x
2 domains =
28 scores

$$\text{skill} = 1 - \frac{|\tau_{\text{obs}} - \tau_{\text{model}}|}{|\tau_{\text{obs}}|}$$

skill = +1 if you are perfect

skill = 0 if you are just guessing

skill < 0 : *you <u>should</u> just guess*



Summary

Lots of records (17000 / 84000) ... and there must be lots more.

Global mean topostrophy $\tau \equiv \mathbf{f} \times \mathbf{V} \cdot \nabla H$ = **+0.22** (normalized)

Topostrophy is greater at (1) higher latitudes and (2) depth

Why? Entropy organizes ocean circ? *What do you think?*

Put this stuff to use: measure models' skills (dynamics skill!)

Outstanding

Need confidence limits, error estimation & compensation.

What is relation of variability to mean topostrophy?

What about atopostrophy? $\alpha \equiv |\mathbf{f}| \mathbf{V} \cdot \nabla H$

Resolve "Arctic" by regions: Amerasian, Eurasian, Barents